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Cockpit Accommodation in USN/USMC Helicopters

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ABSTRACT

Anthropometric accommodation guidance for USN/USMC helicopters is outdated, undocumented, and in some cases nonexistent. Recent reassignments of aviators within the USN/USMC due to poor accommodation have highlighted an area where operational dollars could be saved by safely and correctly assigning candidate aviators to a specific training and career pipeline. These issues were revealed during the course of NAVAIRSYSCOM (PMA-202) Aircrew Accommodation Expansion Program where NAVAIR 4.6 at Patuxent River was tasked to perform a baseline accommodation assessment of in-service USN/USMC aircraft.

The methods used in the program approach were different than procedures historically used to determine USN/USMC aviator suitability or to verify cockpit design. The process used to screen aviators is more closely related to the specification guidance used to develop the aircraft, and a multivariate statistical approach is employed which serves as the basis for determining safe accommodation envelopes for rotary wing aircraft in the USN and USMC. The accommodation envelopes have been developed into Anthropometric Restriction Codes (ARC's) which are used to screen aviator candidates to determine if a career in helicopters is feasible with respect to cockpit accommodation. The revised guidance accounts for:

- Interactions of all anthropometric variables that dictate the proper location of the seat

- Operational use of the Anthropometric Restriction Codes
- Cost avoidance associated with inappropriately assigning aviators

These revised guidelines help to define the acceptable range of aircrew anthropometric dimensions that must be satisfied to achieve safety of flight and mission effectiveness.

INTRODUCTION

BACKGROUND

Anthropometric restriction codes (ARC's) contained in references 1 and 2 are outdated, undocumented, and require the use of a fit check process that is subjective. Recent reassignments of aviators within the USN/USMC have highlighted an area where small improvements to a simple non-clinical test could save operational dollars, and potentially reduce mishaps where ill-suited anthropometrics have been cited as causal and contributory factors. These issues were revealed during the course of the NAVAIRSYSCOM (PMA-202) Aircrew Accommodation Expansion Program where AIR 4.6-Patuxent River was tasked to perform a baseline accommodation assessment of in-service USN/USMC aircraft (reference 3). The methods used in the program approach were different than procedures historically used to determine USN/USMC aviator suitability and verify cockpit design. A multivariate statistical approach was employed and served as the basis for determining the safe accommodation envelopes for each platform/crew station. The revised ARC's and resultant percent

accommodated within this report account for the following:

- Location of the seat with respect to the interacting variables that affect the appropriate seat location
- Operational use of the codes and pipeline relational charting
- Potential cost avoidance associated with the early assignment of aviators to their suitable aircraft via the proposed ARC system presented

These revised ARC's and percent accommodated are established from the aircrew accommodation analyses conducted under reference 3. The revised ARC's define the acceptable range of aircrew anthropometric dimensions that must be satisfied to achieve safety of flight and mission effectiveness.

PURPOSE

The purpose of this effort was to provide revised ARC's for USN/USMC helicopters and to provide an estimated percentage of a given population (reference 4) that is accommodated in each aircraft.

SCOPE OF TESTS

Evaluations of aircrew anthropometric accommodation in AH-1W, SH-60B, UH-1N, and TH-57C aircraft were conducted at NAS Patuxent River, Maryland. The CH-53E and CH-46 evaluations were conducted at MCB Quantico, Virginia. Additional Man-Machine Integration Laboratory (MMIL) work augmented the on-aircraft data collection where subject data were unable to be attained appropriately. Each of the evaluations typically required 30 hours of ground tests conducted over a 3-day period. Aircrew accommodation data were collected in both crew stations for each aircraft. In all measured test trials, subjects were attired in the full complement of

summer flight gear as specified for each aircraft in reference 5. Evaluation of aircrew anthropometric accommodation included the following five functional parameters:

- a. External Field of View (EFOV): ability to obtain Design Eye Point.
- b. Functional Arm Reach: ability to operate critical flight and emergency controls with a locked harness.
- c. Functional Leg Reach: ability to operate pedals.
- d. Leg Clearances: ability to have lower leg clearance to the main instrument panel.
- e. Overhead Clearance: ability to have head clearance to any overhead obstructions.

The ARC's presented within this report do not address these additional accommodation issues: flying aggressive flight profiles, individual aircrew strength, or enlisted crew stations.

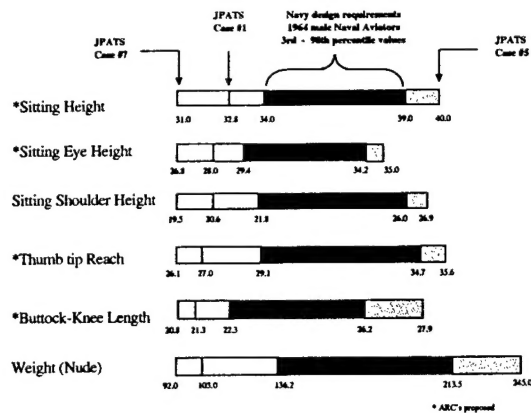
Although the methods employed in this accommodation study differ from those utilized during aircraft design and development, the results reported do not necessarily imply any deficiency with respect to specification compliance by the airframe manufacturer, seat contractors, or the procuring agency.

METHOD

GENERAL

A pool of 10 (on-aircraft evaluation) to 15 (MMIL evaluation) test subjects, representing the range of candidate aviator anthropometric characteristics, as seen in figure 1 and reference 4, were measured in accordance with the methods established by reference 6. Crew station geometry and subject accommodation data were collected using the procedures outlined in reference 7.

Figure 1: Past and Present USN Aircraft Accommodation Specification Criteria



DATA COLLECTION

The crew station geometry measurements were collected by the FaroArm™, a 4-ft long, 6 degree of freedom articulating arm with an accuracy of 0.012 inch. The FaroArm™ is a coordinate measurement machine that takes data such as points, lines, and planes in a three-dimensional coordinate system, and places these features in an AutoCAD® drawing via AnthroCAM™, the software that interfaces AutoCAD® with the FaroArm™. The crew station geometry measurements were made to align the FaroArm™ with the aircraft coordinate reference system, when available, and to record the location of flight control and cockpit control test points, clearance obstructions, and the adjustment ranges of the seat and rudder pedals.

A subject accommodation evaluation was then performed. Specific measurement criteria were as follows:

a. Clearance measurements were taken between the top of the helmet (while the subjects' heads were stationary and upright) and the closest overhead surface.

b. Lower leg clearance distances were measured between the lowest edge of the main instrument panel and the shin while the subjects' feet were resting on the pedals.

c. The ability of each subject to reach and operate the control cyclic and other essential or emergency controls in each crew station was evaluated. Functional reach was evaluated in the Zone 2 condition (shoulder harness locked with maximal stretching of arm and shoulder).

d. External Field of View was evaluated by determining whether each subject could establish a horizontal vision line through the design eye point (DEP).

e. Reach distances to pedals were measured between the full aft position of the pedals and the furthest forward pedal location where full control was achieved.

DATA ANALYSIS

The data generated by the FaroArm™ evaluation was then organized into a Microsoft Excel® worksheet. The data points were reduced into accommodation prediction equations through multiple regression analysis. The independent variables were the subjects' anthropometric measurements and the seat adjustment heights, and the dependent variables were miss/over reach or clearance distances.

These prediction equations were then employed to determine the accommodation envelopes for each anthropometric dimension in each aircraft. The equations exhibit coefficients of determination (R^2) of 0.7 or greater. The standard error associated with each regression equation was generally less than 0.5 inches except for those involving the prediction of arm reach capability where the goal was generally to achieve 1.0 inch or less standard error. Each aircraft and crew station had its own unique set of univariate thresholds established from the regression analyses.

The analysis was based on an expanded range of anthropometric measurements reflecting an anticipated DoD population defined in reference 4. The critical cockpit anthropometric characteristics of the anticipated DoD population are covered in table 1, which

defines USN/USMC Helicopter ARC's in terms of thirteen intervals around four significant cockpit-critical anthropometric dimensions, as noted by the "*" in figure 1.

Table 1: Anthropometric Restriction Codes

Code	Sitting Eye Height (in)	Functional Reach (in)	Buttock-Knee Length (in)	Sitting Height (in)
0	<26	<26	<20.4	<31
1	26-26.4	26-26.4	20.5-20.9	31-31.9
2	26.5-26.9	26.5-26.9	21-21.9	32-32.9
3	27-27.4	27-27.4	22-22.9	33-33.9
4	27.5-27.9	27.5-27.9	23-23.4	34-34.4
5	28-28.4	28-28.4	23.5-23.9	34.5-37.4
6	28.5-28.9	28.5-28.9	26-26.4	37.5-38.4
7	29-29.4	29-29.4	26.5-26.9	38.5-38.9
8	29.5-29.9	29.5-29.9	27-27.4	39-39.4
9	30-30.4	30-30.4	27.5-27.9	39.5-39.9
10	30.5-30.9	30.5-30.9	28-28.4	40-40.4
11	31-31.4	31-31.4	28.5-28.9	40.5-40.9
12	>31.5	>31.5	>29	>41

The proposed revised coding interval system shown in table 1 was used in combination with the resultant univariate analyses to generate the updated and revised anthropometric restriction coding for USN/USMC aircraft. The ARC's are presented in a series of four charts including sitting eye height, functional reach, buttock-

knee length, and sitting height for USN/USMC pilots and copilots.

The revised ARC's which were derived as described above for USN/USMC tactical aircraft, are presented in table 2.

RESULTS AND EVALUATION

The results of these tests indicate recommended minimum pilot sitting eye heights in USN/USMC helicopters range from 27.5 to 28.5 inches. These minimum sitting eye heights are based on external visibility requirements listed in reference 8, which in turn drove the location of the design eye point (DEP).

The results of these tests indicate a recommended minimum pilot thumb-tip reach of 27.0 to 28.5 inches for the operation of primary flight controls and immediate action emergency controls. As a two-axis seat moves upward and aft, the occupant is pulled away from the primary flight controls, instrument panel controls, and center console controls, but is placed closer to the DEP and overhead controls. There is a strong relationship between obtaining the requisite downward, over-the-

Table 2: Anthropometric Restriction Codes for Helicopters

Table 2: Anthropometric Restriction Guide for Helicopters														
Sitting Eye Height (SEH) in inches														
		0	1	2	3	4	5	6	7	8	9	10	11	12
		<25	26-26.4	26.5-27	27-27.5	27.5-28	28-28.5	28.5-29	29-29.5	29.5-30	30-30.5	30.5-31	>31.5	
Aircraft	Crew Station													
AH-1W	Forward													
AH-1W	Aft													
CH-46	Both													
CH-53	Both													
SH-60B	Both													
TH-57	Both													
UH-1H	Both													
Thumb Tip Reach (TTR) in inches														
		0	1	2	3	4	5	6	7	8	9	10	11	12
		<25	26-26.4	26.5-27	27-27.5	27.5-28	28-28.5	28.5-29	29-29.5	29.5-30	30-30.5	30.5-31	>31.5	
Aircraft	Crew Station													
AH-1W	Forward													
AH-1W	Aft													
CH-46	Both													
CH-53	Both													
SH-60B	Both													
TH-57	Both													
UH-1H	Both													
Buttock Knee Length (BKL) in inches														
		0	1	2	3	4	5	6	7	8	9	10	11	12
		<20.4	20.5-20.9	21-21.9	22-22.9	23-23.4	23.5-23.9	24-24.4	24.5-24.9	25-25.4	25.5-25.9	26-26.4	26.5-26.9	>29
Aircraft	Crew Station													
AH-1W	Forward													
AH-1W	Aft													
CH-46	Both													
CH-53	Both													
SH-60B	Both													
TH-57	Both													
UH-1H	Both													
Sitting Height (SH) in inches														
		0	1	2	3	4	5	6	7	8	9	10	11	12
		<31	31-31.9	32-32.9	33-33.9	34-34.4	34.5-34.9	35-35.4	35.5-35.9	36-36.4	36.5-36.9	37-37.4	37.5-37.9	>41
Aircraft	Crew Station													
AH-1W	Forward													
AH-1W	Aft													
CH-46	Both													
CH-53	Both													
SH-60B	Both													
TH-57	Both													
UH-1H	Both													

nose field of view capability and maintaining full reach capability to all controls.

The results of these tests indicate that a buttock-knee length of greater than 21.0 inches is recommended for rudder pedal access. In general, these measurements indicate that a buttock-knee length of less than 28.0 inches will safely clear the main instrument panel.

A percentage of the population defined in reference 4 was determined by dividing the number of successful accommodation values by the total number of individuals in the DoD Standard Aircrew Population.

Based on the analyses, table 3 presents the percentage of personnel accommodated for each respective platform/crew station:

Table 3: Helicopter Percent Accommodated

Aircraft/Crew Station	Percent Accommodated
AH-1W, FWD	90.40%
AH-1W, AFT	90.60%
CH-46, Both	83.40%
CH-53, Both	83.40%
SH-60B, Both	61.70%
TH-57C, Both	83.00%
UH-1N, Both	89.40%

Limitations to accommodating an increased percentage of smaller dimensioned personnel in the above USN and USMC helicopters were noted. These limitations included the ability to maintain external field of view simultaneously while maintaining a capability to reach and operate primary flight controls or other immediate action emergency controls while the seat restraint system was locked. Additionally, limitations to accommodating an increased percentage of larger dimensioned personnel in the above USN and USMC helicopters were noted. These included the ability to safely clear cockpit structures while seated in the aircraft. The ARC's and resultant percent accommodated presented within this report do not address additional accommodation limitations due to the effects of flying

aggressive flight profiles or based on individual aircrew strength.

CONCLUSION

Accommodating the anthropometrically expanded aviator population of today's Navy poses quite a challenge for both aircraft manufacturers and crew systems engineers. It requires a well-balanced combination of teamwork, technology, skill, and persistence. Obtaining accurate anthropometric data is crucial in assessing existing aircraft accommodation and providing reengineering recommendations.

An examination of previous ARC's reveal that the important combination of tasks that must be performed in an aircraft have been inadvertently overlooked and led to the need for costly fit checks. The revised ARC system looks closely at all aspects of flight that must occur dynamically. These ARC's will enhance the aviator assignment process by safely bringing together the best overall mix of aircrew and aircraft while eliminating the need for expensive fit checks.

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Biographies:

Heather D. Tucker has been employed by NAVAIR 4.6 in Patuxent River, Maryland, since 1996, as a project engineer and currently the acting team leader of the Aircrew Accommodation Expansion Program. She is responsible for data collection and analysis of anthropometric assessments of Navy aircraft. She has also developed a software program to analyze aviator accommodation in all existing aircraft and predict aviator candidate pipeline assignments. She is certified to take anthropometric measurements on humans, and is also a certified operator of the FaroArmTM, a coordinate measurement machine. She was previously a member of the Active Network Guidance in Emergency Logic (ANGEL) program, which is intended to integrate several automated safety features into Navy aircraft. Ms. Tucker received a Bachelor of Science in Industrial Engineering from West Virginia University, and a Master of Science in Systems Management/Operations Research from Florida Institute of Technology.

Jennifer J. Crawford currently works for NAVAIR 4.6 as a project engineer supporting the Aircrew Accommodation Expansion Program and other platform-specific projects. She has been a member of this team for four years performing duties such as test coordination and preparation, and data collection and analysis on anthropometric assessments of US Navy and Marine cockpits. She is certified to operate the FaroArmTM, a

coordinate measurement machine, and is also certified to take anthropometric measurements on humans. She is a US Navy representative to the Air Standardization Coordinating Committee (ASCC) for Aerospace Medicine, Life Support, and Aircrew Systems (Working Party 61-Project Group 105). Ms. Crawford received her Bachelor of Science in Industrial Engineering from West Virginia University, and is currently pursuing a Master of Science in Engineering Management from Florida Institute of Technology.